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GaSb epitaxial layers: MOCVD growth and characterization

1. INTRODUCTION

Interest to research GaSb is caused by an opportunity of its use as a material of active layers of optoelectronic devices in near IR range of spectrum (l ~ 2 microns), such as lasers, light-emitting diodes, solar and thermophotovoltaic converters. For all listed applications doping and purity of layers GaSb are actual, in particular, for thermophotovoltaic converters the material with low concentration and high mobility of own carriers is necessary.

The origin p-type conduction of GaSb alloys was often attributed to native lattice defects (i.e. Sb vacancies), antisite defects (Ga atoms at Sb sites), and defect complex ($V_{Ga}Ga_{Sb}$). Until recent time the liquid phase epitaxy (LPE) from Ga-, Sb-, Pb- and Bi-enriched melts was been the basic method of reception GaSb. Use Bi as solvent has allowed to receive rather low concentration of acceptors (10^{16} cm^{-3}) in GaSb [1].

Use of nonequilibrium methods, such as a metalorganic chemical vapor deposition (MOCVD) [2] and a molecular beam epitaxy (MBE) [3] allows to receive concentration much less (about 10^{15} cm^{-3}). It is connected with influence of technological factors on stoichiometry of grown GaSb epitaxial layers; the deviation from stoichiometry raises the concentration of native structural defects.

In this paper we report the MOCVD growth of GaSb with varying V/III ratio. The main goal of this work is defining conditions of the growth of GaSb-layers with the lowest concentration of own carriers.

2. EXPERIMENTS

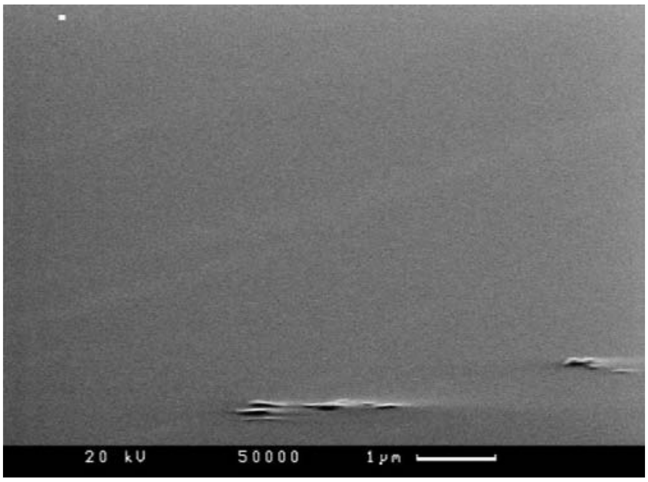
The epitaxial growth was carried out in a horizontal, low pressure (100 mbar) MOCVD reactor. The precursors were triethylgallium (TEGa), trimethylantimony (TMSb). The carrier gas was Pd-purified H_2 at a total flow of 5.5 l/min, Te-doped GaSb and semi-insulating GaAs were used as substrates. First a wall all the substrates were cleaned by degreasing in organic solvents and deionized water, secondly they were treated by etching solutions. GaSb substrates were etched in solution (H_2O:H_2O_2:40% tartaric acid:HF=25:25:22:1,5) during 1 min. GaAs wafers were treated in the standard chemical etching solution (H_2SO_4:H_2O_2:H_2O=5:1:1). Then all the wafers were rinsed with deionized water, blown dry with filtered nitrogen and loaded into the glovebox. Heating of substrates up to temperature of growth (600 ^{0}C) was carried out in an automatic mode five infra-red lamps, substrates were rotated for improvement of layers uniformity by an additional stream of hydrogen of 300 ml/min. The ratio of mole streams of sources of elements of the fifth and third group (v^V/v^{III}) varied from 0.9 to 5.

The surface morphologies were examined by means of optical microscopy and electron microscopy (“CamScan”). X-ray diffraction (“DRON-2”) was used to evaluate the crystalline quality of the epilayers. Standard Hall measurements were performed to determine the electrical properties of the GaSb epilayers grown on semi-insulating GaAs substrates.

For measurement of the photoluminescence spectra it was used the Argon laser (λ =514.7 nm) and photodetector based on PbS.

3. RESULTS AND DISCUSSION

The morphology of epitaxial layers GaSb is sensitive to ratio of mole streams of sources of elements of the fifth and third group (v^V/v^{III}). The layers which have been brought up at $v^V/v^{III}<1$, had a matte surface with droplets of gallium; at $v^V/v^{III}>1$ the layers had mirror smooth surface. Single defects on a surface of the GaSb epitaxial layers (see fig.1) are probably connected with quality of used substrates. The minimal ratio (v^V/v^{III}) for growth of GaSb epitaxial layers closed to stoichiometry is equal 1, that corresponds with results represented in [4].



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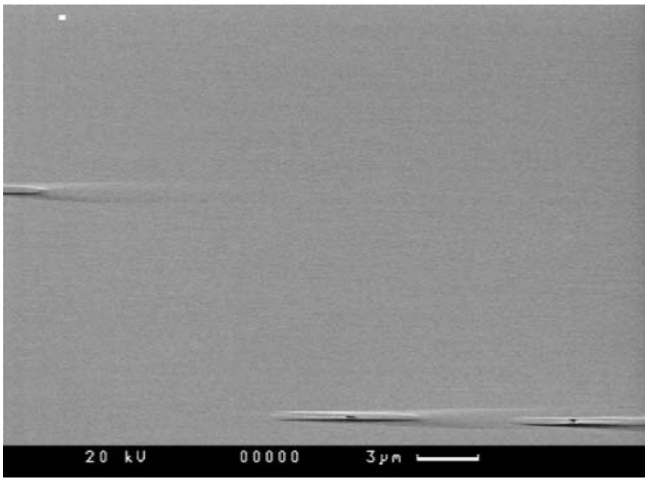

б)

Fig 1. Surface morphologies of *GaSb* films*: a) V/III=1,5; б) V/III=1,2.*

Typical X-ray diffraction result for eptitaxial layer GaSb grown at ratio $v^V/v^{III}=2$ is shown on Fig. 2. For comparison X-ray rocking curve for substrate is resulted. Thickness of GaSb epitaxial layer is about 2 microns, that indicates on the contribution of a substrate in increase FWHM of X-ray curve of structure. FWHM of rocking curve of the structure (19 acr.sec.) was noticeably less than FWHM of rocking curve of substrate (44 arc.sec.), that allows to judge good crystal perfection of grown epitaxial layers.

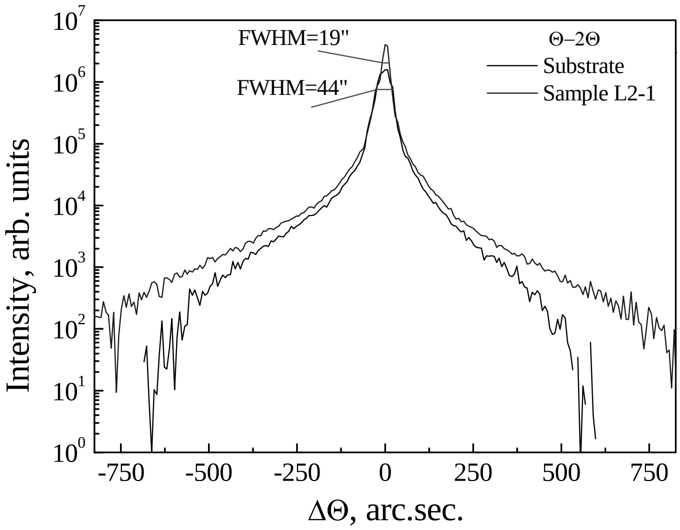

Fig 2. X-ray diffraction of epitaxial layer *GaSb*, grown on *GaSb* substrate.

For measurement of electric properties GaSb-layers were grown on GaAs substrates - "satellites". All GaSb layers had “p” - type of conductivity, the greatest mobility of holes was 3110 cm^2/Vs at 77 K and 630 cm^2 /Vs at 300 K in the samples which have been brought up at the ratio mole streams v^V/v^{III}=1. Concentration of holes was $9,8\cdot10^{15}cm^{-3}$ at 77 K and $3\cdot10^{16}cm^{-3}$ at 300 K, accordingly, that comes nearer to the received values in work [4]. Figures 3 and 4 show dependences of mobility and concentration of own carriers on the v^V/v^{III} ratio. It is visible, that the minimums of concentration and mobility of holes at 77K and mobility of holes at 300K correspond to v^V/v^{III}=3. The nature of these is planned to be find out after additional researches.

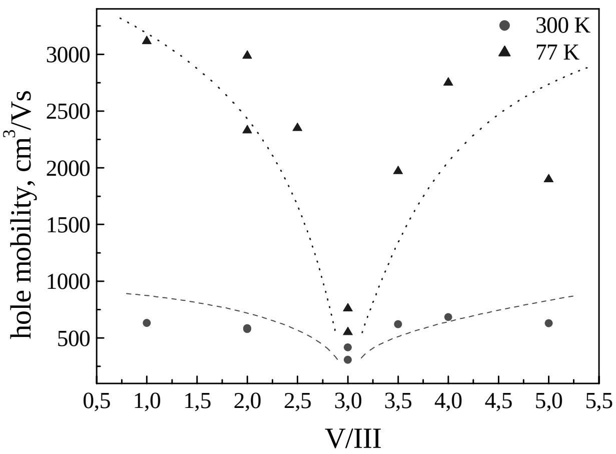

Fig. 3. *Hole mobility versus V/III ratio.*

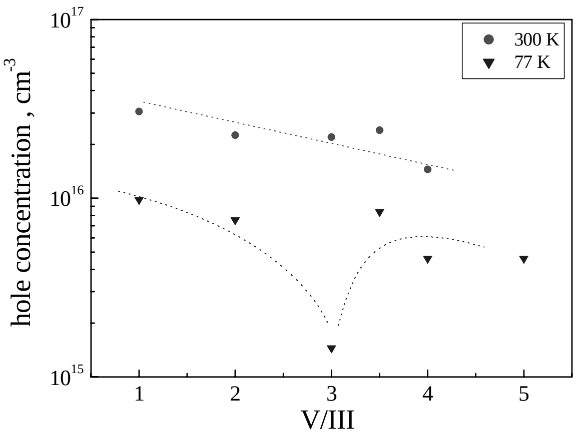

Fig. 4. *Hole concentration versus V/III ratio.*

The sample grown at v^V/v^{III}=2 shows the maximal intensity of a photoluminescence (see Fig. 5) in comparison with ones obtained at other v^V/v^{III} ratio. The spectrum of a photoluminescence of a substrate on which growth was carried out is shown on this figure also. It is visible, that the maximum of radiation of an alloyed substrate corresponds to energy 710 meV (*Eg=800* meV at 77K), that is connected with deep donor levels of tellurium (Te), and on a spectrum of a photoluminescence of a layer three peaks ~710, 775 and 800 meV are visible.

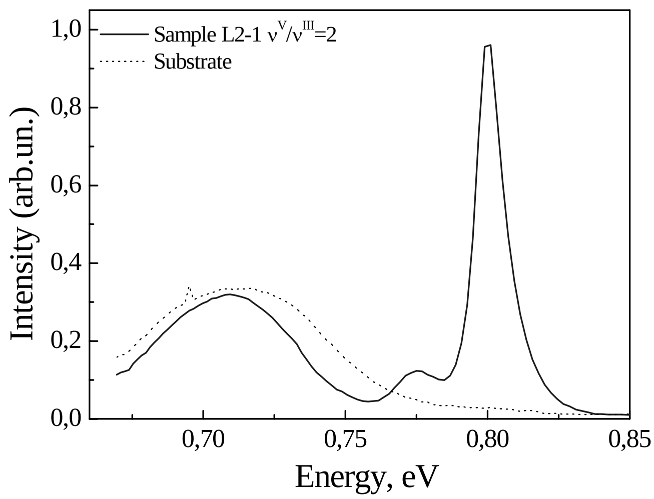

Fig 5. *PL energy (77K)of epilayer GaSb and substrate.*

The peak of a photoluminescence with a maximum 800 meV (FWHM 12 meV) is caused by interzone transitions; the peak of a photoluminescence with a maximum 775 meV is caused by recombination through the acceptor levels connected to vacancies (V_{Ga} and Ga_{Sb}). The peak of a photoluminescence 710 meV is apparently connected with passing of long-wave radiation of an alloyed substrate through effectively more wide-gap epitaxial layer.

4. CONCLUSION

The technology regimes of growth of not alloyed GaSb layers are developed. The best morphology of a surface was observed for the samples which have been grown at v^V/v^{III} ratio between 1 and 2 (T_p=600 ^{0}C).
All obtained layers had p-type of conductivity, thus the greatest mobility of holes has made 3110 cm^2/Vs at 77 K and 630 cm^2/Vs at 300 K in the samples had been grown at v^V/v^{III} = 1; concentration of holes $9{,}8\cdot10^{15}cm^{-3}$ at 77 K and $3\cdot10^{16}cm^{-3}$ at 300 K was measured, that is close to the best published data.
All layers had peak of a photoluminescence with energy ~800 meV (77 K) caused by interzone transitions, the maximal intensity of a photoluminescence peak with FWHM=12 meV has been measured in the sample had been brought up at v^V/v^{III}=2.

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